# LOFAR Scientific Memorandum #2: LOFAR: A crucial step for probing the electromagnetic spectrum at even lower frequencies

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## 1 For the non-technical reader

The terrestrial ionosphere becomes opaque to radio waves of about 10 MHz and lower, and the less dense interplanetary medium becomes opaque to radio waves of a few tens of kHz and lower. Hence, the frequency range from a few tens of kHz to a few MHz carries information of astronomical interest and observations in this part of the spectrum are expected to yield rich and exciting scientific dividends. However, in order to capture this information, it will be necessary to place our detectors above the ionosphere. An exploration of these three decades of spectrum will open up the last remaining part of the electromagnetic spectrum accessible from the terrestrial neighbourhood. A satellite-based very low frequency radio interferometer will be required to investigate these unexplored regimes of the electromagnetic spectrum at scientifically desirable resolution and sensitivity.

In order to reach the performance levels required to achieve the scientific objectives, a space based interferometer and LOFAR have significant overlap in conceptual and technical challenges that need to be met. The solutions implemented for LOFAR and the experience gained from them will be very useful step towards a space interferometer. The detailed and reliable information of the low frequency sky obtained by LOFAR will significantly benefit space based low frequency radio astronomy missions by providing them a firm anchor point from which to extend the information to even lower parts of the spectrum.

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## 2 For the technical reader

The plasma frequency of the interplanetary medium (IPM) is a few tens of kHz and that of the terrestrial ionosphere varies from a few MHz to a few tens of MHz (depending upon the time of the day, the location on the Earth, the phase of the solar cycle, etc.). The waves lying in this part of the spectrum originating from distant reaches of the universe do reach the Earth's neighbourhood but are unable to penetrate to ground because of lack of transparency of the ionosphere. In order to access this last unexplored part of the spectrum which brings us meaningful information of cosmic objects, it will be necessary to place our detectors above the ionosphere.

An exploration of this band with the resolution and sensitivity required to meet the scientific objectives will require a dedicated satellite based interferometer in space. Various things have led to a renewed interest in a space interferometer mission. The space technology is now mature enough to meet reasonable formation flying requirements for a large range of orbits. The progress of technology has made the formerly hopelessly large telemetry requirements seem more realistic. Large dynamic range broad-band tunable receiver technology is no longer a considerable challenge in the present context.

At the large wavelengths at which this instrument will work, there will be no option but to use short dipoles as the basic receiving elements on-board the satellites. In addition, the relative motion of satellites will lead to a rapidly changing baseline configuration. Calibration and analysis of the data from such an interferometer, which has practically the entire sky in its field of view and rapidly changing baselines, requires a complete shift from the conventional synthesis imaging techniques.

Though for different reasons, LOFAR's data calibration and analysis strategy is designed to meet practically the same challenges. LOFAR's unique needs to calibrate in near real time, due to the time varying ionosphere, the necessity to image very large fields of view and exceptionally large dynamic range requirements necessitate the first bold steps towards meeting these challenges. The experience gained from LOFAR will pave the way for future space based missions. The lessons learnt from LOFAR will play a crucial role in formulating the analysis and calibration strategy for these missions.

One of the most important data products envisaged from LOFAR is the Global Sky Model (GSM). The GSM is envisaged to be a synthesis of the detailed information of the entire low frequency sky visible to LOFAR and will be continuously refined during LOFAR's operational life time. It will form an exceptionally useful resource for the space-based missions as it will provide a secure anchor point to the space missions from where to bootstrap in order to push the knowledge of the radio sky to lower frequencies. The GSM will greatly enhance the productivity of space based missions and reduce the complexity of their calibration procedures.

The inputs from a ground based low frequency telescope, which will provide a good model for the low frequency sky and verify efficacy of analysis procedures, is practically the only remaining step which will provide the needed missing information to plan a satellite based interferometry at even lower frequencies.